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CHAPTER THREE

The Nature and Nurture of Vocational Interests

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VOCATIONAL PSYCHOLOGY IS KNOWN for its interest measurement. Millions of people take a vocational interest inventory each year to learn more about themselves. The field's theories of career choice and development, however, actually say little about how interests develop. All the major psychological theories of careers (see Brown & Brooks, 1996) state that at least some career-relevant traits (e.g., abilities, interests) are genetic to some extent, but none ventures much opinion about the magnitude or relevance of that heritability. For the most part these theories take stable traits as their starting point and then focus on how various personal attributes and social influences affect career development. The theories differ considerably in how much importance they attach to vocational interests relative to other traits and circumstances that influence career choices (e.g., compare Holland [Spokane, 1996] with Gottfredson, 1996), but all seem equally silent when it comes to explaining how interests themselves originate.

This theoretical lacuna is understandable. Much less was known about the genetics of human behavior when most of today's vocational theories were formulated, and the one theory about the childhood experiential origins of interests (Roe, 1956) fared badly when tested. But the situation is different today. The last decade of behavioral genetic research has produced a torrent of relevant information, much of it counterintuitive. It turns out that even behavioral geneticists had been mistaken in their assumptions about how genes and environments influence human traits and behaviors. As a result the developmentalists among them (e.g., Scarr & McCartney, 1983) have begun to reconceptualize human development in exciting new ways—ones, moreover, that vocational psychologists should find very congenial. As I shall try to demonstrate here, behavioral genetics not only provides powerful new tools for answering old questions about vocational interests, but it also poses intriguing new questions about their origins and development.

WHAT IS BEHAVIORAL GENETICS?

Behavioral genetics is a method for studying *variability* among individuals. It asks, most simply, to what extent observed (phenotypic) differences among individuals can be traced to differences in genetic versus nongenetic sources. As such it is another tool in the long tradition of individual differences research. What is special is that it uses genetically sensitive research designs to trace the impact of both genetic and environmental sources of variation in complex human traits and behaviors. Behavioral geneticists use knowledge about the genetic relatedness of different family members, together with natural experiments in the relatedness of their environments, to disentangle genetic and nongenetic influences in development. As I will describe, some of the most dramatic findings in behavioral genetics concern the effects of environments.

Genetic relatedness among family members ranges from zero (adopted siblings and their adoptive parents) to 1.0 (identical twins). Individuals share exactly half of their segregating genes with each biological parent, an average of half with their biological siblings, one quarter with half-siblings and grandparents, an eighth with uncles, and so on. If a trait were entirely genetic in origin (and if we assume that all genetic influence is additive), then relatives would be phenotypically similar to each other in proportion to their genetic similarity. Thus identical twins would (absent measurement and sampling error) correlate 1.0, biological parents would correlate .5 with their children (as would fraternal twins with each other), and adoptive family members would be no more similar to each other than complete strangers. (When there are nonadditive genetic effects, only identical twins share them, which means, for example, that the phenotypic similarity of fraternal twins will be less than half that of identical twins.)

In most families, members share both genes and environments, so any similarity between parents and children or siblings may be due both to shared genes and shared environments. Behavioral genetics capitalizes on cases where genetic and environmental relatedness diverge markedly. Identical twins reared apart share 100% of their genes but little or none of their postnatal environment. (There is disagreement about whether prenatal environments tend to make twins more alike [Daniels, Devlin, & Roeder, 1997] or less alike [Jensen, 1997; see also Phelps, Davis, & Schartz, 1997].) The correlation between identical twins thus provides a direct estimate of an attribute's heritability. In contrast, adoptive siblings share none of their genetic heritage but they do experience the same family environments, that is, they are only "environmental relatives." Their correlation on an attribute therefore directly estimates the effect of shared rearing environments on that attribute. Indirect estimates of heritability can be obtained from other combinations of environmental and genetic relatedness—for example, by doubling the difference between the correlations for identical and for fraternal twins reared together. All heritability estimates, whether direct or indirect, rely on the truth of various assumptions (such as degree of assortative mating among parents, selective placement of adoptees, absence of nonadditive effects), all of which can be tested (e.g., Loehlin, 1992; Plomin, DeFries, McClearn, & Rutter, 1997, pp. 73–75).

These straightforward estimates of heritability and environmentality illustrate the logic behind behavioral genetic analyses, but quantitative behavioral genetics has actually advanced far beyond such simple analytical methods. Today structural equation modeling is used to combine data from different kinds of samples (adoptees, identical and fraternal twins reared apart, biological siblings and half-siblings, etc.) and to test different models of genetic and environmental influence (Loehlin, 1992; Plomin, DeFries et al., 1997). Such modeling can be used to test complex hypotheses, for example, about when in the life cycle genes and environments exert their effects to produce stability or change in various attributes.

The early research focused mostly on intelligence, cognitive disabilities, and psychopathology, but much evidence has now begun to accumulate on personality and, to a lesser extent, interests and attitudes. Heritabilities have been estimated for many such attributes, and I will briefly summarize the most pertinent, focusing in particular on evidence for adolescents and adults. The most illuminating research, however, moves far beyond estimating heritability, so I will concentrate here on new developments that seem particularly important for the study of vocational interests.

HERITABILITY: THE OLD NEWS

It was still big news a decade ago when behavioral geneticists periodically came forward with evidence that yet another human trait or behavior is heritable: for example, depression or schizophrenia. No longer. It would be news today if some trait were found to be *not* at all heritable.

Heritability, or h^2, is a proportion of variance and therefore can range anywhere between zero and 1.0. Specifically it is the proportion of variance among individuals in a phenotypic characteristic, such as IQ, that is due to genetic variance in the population in question. The square root of heritability, or h, is the correlation between genotypes and phenotypes on that attribute. To illustrate, many human traits have heritabilities around 0.5 (50% of observed differences are genetic), which means that the phenotypes for those characteristics correlate about 0.7 (the square root of .5 rounded off) with their genotypes.

General intelligence is highly heritable, with estimates generally ranging between 0.6 and 0.8 in adulthood (Bouchard, 1997b), meaning that 20% to 40% of adult IQ differences can be attributed to differences in environment (and measurement error). Recent studies of identical twins reared apart, for example, yield heritabilities around 0.8 in late adulthood (Plomin, Pedersen, Lichtenstein, & McClearn, 1994). Specific mental abilities (e.g., verbal, spatial) are somewhat less heritable (0.4–0.6; McGue & Bouchard, 1989; Pedersen, Plomin, Nesselroade, & McClearn, 1992), as are specific information-processing skills (e.g., acquisition speed, 0.3–0.6; McGue & Bouchard, 1989). Heritabilities for personality traits generally average 0.4–0.5 (Bouchard, 1997a), as is true also for vocational interests (Moloney, Bouchard, & Segal, 1991; Betsworth, Bouchard, Cooper, Grotevant, Hansen, Scarr, & Weinberg, 1994) and work values (Keller, Bouchard, Arvey, Segal, & Dawis, 1992). For comparison purposes, consider the heritabilities for various anthropometric and physiological variables from a study of identical twins reared apart: fingerprint ridge count (.97), height (.86), weight (.73), systolic blood pressure (.64), and heart rate (.49; Bouchard, Lykken, McGue, Segal, & Tellegen, 1990).

Even behaviors and personal circumstances that are often assumed to be entirely environmental in origin turn out to be somewhat heritable: specific social attitudes (up to 0.6; Tesser, 1993), job satisfaction (0.3; Arvey, Bouchard, Segal, & Abraham, 1989), quality of social support (0.3; Plomin & Bergeman, 1991), and life events (0.4 for controllable ones such as divorce, and 0.2 for uncontrollable ones such as death of a child or spouse; Plomin, Lichtenstein, Pedersen, McClearn, & Nesselroade, 1990, p. 29). Self-esteem (McGuire, Neiderhiser, Reiss, Hetherington, & Plomin, 1994; Neiderhiser & McGuire, 1994) and the nature of many of one's personal relationships are also somewhat heritable: for example, attachment (Ricciuti, 1993), empathy (Zahn-Waxler, Robinson, & Emde, 1992), parental warmth (Rowe, 1981, 1983), and sexual orientation (Bailey & Pillard, 1991; Bailey, Pillard, Neale, & Agyei, 1993), but not style of romantic love (Waller & Shaver, 1994).

Individuals obviously are not born predestined to divorce or with a gene to disfavor the death penalty, censorship, or nudist camps (heritabilities of 0.5, 0.4, and 0.3; Tesser, 1993, p. 130). Genes are only codes for building proteins. However, those proteins create hormones and neurotransmitters that can affect personality, interests, and aptitudes, which can in turn affect interpersonal relations, socioeconomic trajectory, and world view. Heritability alone obviously says nothing about the mechanisms by which genes influence behavior.

It is important to note several other things that heritabilities do not tell us. They do not say how much of any single person's intelligence, extraversion, life events, or the like is due to genetic versus environmental influence. Heritability concerns only variability in a population. Nor do heritabilities say anything absolute about genetic influence on variability. Phenotypic variability, the denominator in calculating heritability, is the sum of variance due to genes and variance due to nongenetic factors. Reducing variability in relevant environments (say, through equalizing nutrition or opportunity) shrinks the denominator and thus necessarily increases the ratio comprising the heritability estimate. If we all lived in identical environments, heritabilities would be 1.0 because all remaining phenotypic differences among us would be genetic in origin.

Heritabilities, in other words, must be interpreted in context. They are always relative to the environment in which they were ascertained, which makes it very important to keep in mind the demographics and historical era of the populations studied. Most studies have been carried out in the United States and Western Europe, and they have not sampled from the extremes of advantage or disadvantage in these settings. Heritabilities allow some inferences about the malleability of traits in the environments where they were ascertained, but they say little or nothing about the molding power of existing or potential environments that were not captured in the research—for example, extremely deprived conditions or novel interventions. To take another example, if a shared national culture led all its members to behave differently than they would in another society, but if that culture did not increase or decrease the *differences* among its members, then its influence (on the mean) would not register in behavioral genetic studies restricted to that culture. Constants do not affect variance.

In sum, a wide range of individual differences in psychological traits is moderately to highly heritable, including the major dimensions of mental ability, personality, and vocational interests. Even less trait-like attributes and behaviors are somewhat heritable too: for example, social attitudes and life events. Until proven otherwise, developmental studies must now presume that every personal attribute under study is at least somewhat genetically influenced. No inferences about the magnitude of environmental effects on development can be safely drawn without using either an experimental or genetically sensitive research design.

NEW SURPRISES

The surprises coming out of behavioral genetics challenge our most basic assumptions about human development. I review five sets of unexpected findings and the new conceptions of development to which they lead. The research on career-relevant traits has focused primarily on intelligence, less on personality, and little on vocational interests. However, the rethinking prompted by the behavioral genetic research on intelligence and personality has direct implications for vocational development. I outline only a few, but they show the promise that behavioral genetics holds for advancing our understanding of vocational interests.

Heritability of IQ Rises with Age

Social scientists have long assumed that the events and circumstances of one's life cumulate and compound in shaping traits and behaviors. The more advantages or disadvantages we experience, and the earlier we experience them, the more powerful they are presumed to be in shaping who we become. Hence the frequent call for more and earlier childhood interventions to enhance the cognitive development of children from disadvantaged homes.

Much to the surprise of behavioral geneticists themselves, the research on intelligence shows precisely the opposite trend for environmental effects on IQ. They *fade* with age. The many behavioral genetic studies of intelligence, both longitudinal and cross-sectional, reveal that heritabilities rise from 0.4 or less in childhood to 0.6 in adolescence to 0.8 late in life (Bouchard, 1997b; Plomin & Petrill, 1997). This means, astonishingly, that IQ phenotypes correlate 0.9 with genotypes by late adulthood. Plomin, Fulker, Corley, and DeFries (1997) have just documented the same process for specific cognitive abilities (verbal, spatial, speed of processing, and recognition memory): "Adopted children resemble their adoptive parents slightly in early childhood but not at all in middle childhood or adolescence. In contrast, during childhood and adolescence, adopted children become more like their biological parents, and to the same degree as children and parents in control families" (p. 442). It is possible, of course, that a childhood IQ or temperament could deflect a life in one direction rather than another by affecting

events and opportunities at the time (e.g., admission to or expulsion from a good school). However, the traits themselves may move inexorably closer to their genetic substrate, at least in Western societies.

Evidence on age trends in the heritability of personality is less clear, partly because there are so many personality traits. However, the trends that are found involve increased heritability, both during childhood and adulthood (Plomin, DeFries et al., 1997, p. 202). I know of no data regarding age trends in heritability for vocational interests.

The theory that Scarr (Scarr & McCartney, 1983) has proposed to explain the counterintuitive trend in IQ heritabilities provides a conception of human development that should resonate well with vocational psychologists. She argues that as people become more autonomous with age, they take a more active role in shaping their lives. They are better able to choose experiences and modify their environments in line with their genetic proclivities. Scarr's is one of several theories (e.g., Bouchard, Lykken, Tellegen, & McGue, 1996) that explicate how genes drive experiences, which in turn influence development. Social scientists have long stressed that our experiences shape us, but they have missed the fact that our genetic propensities help to construct those very experiences and that those experiences augment, not negate, the expression of genotypes.

There are two general ways in which people's genes structure their experience: by influencing their *exposure* and their *sensitivity* to environments. These are referred to, respectively, as gene–environment (g–e) correlations and gene–environment interactions. Gene–environment correlation means that genetic propensities are correlated with individual differences in experience. Genotypes are not randomly distributed across environments. Stated another way, there are genetically induced risks of exposure to different experiences, some good (social support; Bergeman, Plomin, Pedersen, McClearn, & Nesselroade, 1990; Kessler, Kendler, Heath, Neale, & Eaves, 1992) and some bad (trauma or childhood accidents; Lyons, Goldberg, Eisen, True, Tsuang, Meyer, & Henderson, 1993; Phillips & Matheny, 1995).

There are three types of g–e correlation, commonly called passive, active, and evocative (or reactive). Passive exposure occurs when children passively inherit from their parents family environments that are correlated with their genotypic propensities. The child's environments and propensities are correlated because both flow from the parental genotypes. For example, musically or intellectually gifted parents are likely to provide their children with both environments and genes that are conducive to developing musical or intellectual talent.

Children are not simply passive, neutral figures within their environments, however. Far from it. Gregarious youngsters actively seek out different experiences than do shy ones, and bright students pursue different challenges than do athletic ones. These are examples of *active* g–e correlation. On the other hand, children with different traits evoke different reactions from their environments, creating *evocative* g–e correlations. For instance, aggressive children provoke hostility among peers, and smart children evoke different kinds of encouragement and opportunities than do their intellectually average or retarded siblings. Our gene-driven individuality prompts parents, peers, and others to treat us differently than they do other phenotypes. We evoke different developmental environments for ourselves. Any parent will recognize these processes upon reflection. Parents do not treat their children alike, oblivious to their differences in talent, taste, and temperament. Nor is parent–child interaction and influence a one-way affair. Many a parent (this one included) often feels that it is the child who shapes the parent's behavior.

G–e *interaction* is a different phenomenon. It simply means that the same environment has different effects on different genotypes. That is, people are differentially responsive, sensitive, or susceptible to the same circumstances, be they pharmacological, educational, or social. For example, stressful life events produce more depression among people who are genetically at risk for it (Kendler, Kessler, Walters, MacLean, Neale, Heath, & Eaves, 1995). Similarly some people are more susceptible to criminal environments. Mednick, Gabrielli, and Hutchings (1984) found that criminal behavior among adoptive parents did not lead to criminal behavior among their adopted children unless the adoptees were at genetic risk, that is, had *biological* parents with criminal convictions. Responsiveness to good environments can also differ. For instance, providing musical instruments, lessons, and encouragement to children will result in quite modest talent development among most (many of whom will resist the opportunity), creditable achievement by some, but prodigious feats for a handful.

Perhaps paradoxically, the finding that IQ heritability increases with age has led to developmental theories, such as Scarr's, which emphasize that development results from people interacting with their environments, much of that interaction in turn being driven by the individual's own genetic propensities. Such theory seems quite consistent with vocational psychology's emphasis on the importance of person–environment fit and congruence and on career choice as a process by which individuals implement their self-concepts in order to achieve that fit. In another parallel, vocational theories view the self-concept as incorporating or reflecting one's major personal traits. Neither set of theories presumes that the "self" is genetically fixed, but only that it is constructed in line with inner propensities that in turn help produce formative experiences.

In this sense, vocational psychology has anticipated the new thinking on human development. However, current career theories fall short in two key respects. First, none provides a good account of how career-relevant traits themselves develop. To take a specific example, my own theory of circumscription and compromise (Gottfredson, 1996), although focusing more than most on career development in childhood, fails to address the process by which people shape their experiences and in turn are shaped by them. As in some other theories, crucial personal traits just seem to appear on the scene already fully developed or to unfold unaided.

Second, the emphasis by many theories on "social learning" overstates or misstates the role of learning in development. It often reflects what Rowe (1997) has called "passive exposure theory," in which learning is thought to be primarily a function of exposure governed by families, schools, and other social agents. Change the nature and amount of exposure, and the learning changes accordingly for all those exposed. The new behavioral genetic perspective emphasizes, however, that much exposure and experience, and thus much learning and reinforcement, is self-directed. Even when environments are imposed, people tend to remake them in various and unexpected ways, thus redirecting learning more in line with their genotypes. As noted before, learning therefore tends to magnify, not muffle, the expression of genotypes.

As others have noted, it is crucial to understand the hyphen in nature-nurture—that is, the interplay of genes and environments via experience. This raises a new set of questions for vocational psychology. What *is* the gene-prompted process by which people select, avoid, and attach meaning to their experiences and in the process express, discover, and further develop their interests, abilities, and temperaments? What menus of experience and exploration do environments typically provide (e.g., relevant to Holland's [1997] RIASEC hexagon) for testing and developing interests and aptitudes? How do the menus offered differ by age, sex, or personality type of child (passive and evocative g–e correlation)? How do these youngsters pick and choose from their menus of experience or expand the menus they are offered (active g–e correlation), and how do the effects of experience, exploration, and interventions vary from child to child (g–e interaction)?

If traits develop only in transaction with environments, the opportunities for and the nature of those transactions are critical.

IQ-Relevant Environments Are Partly Genetic in Origin

Social scientists tend to think of family and social environments as powerful, outside forces impinging on individuals, much like the heavens raining down on annoyed picnickers or grateful farmers. Thus developmentalists have long used measures such as the *Home Observation for Measurement of the Environment* (HOME) to study the effects of family environments on infants and toddlers. In like fashion, psychologists and sociologists have sought to catalogue the impact of parental status, encouragement, attitudes, and interests on adolescent career development. The previous discussion of gene–environment correlations indicates, however, that environments do not exist just "out there" independent of the individuals presumably subject to them. Environments themselves are often heritable because their occupants make, remake, and interpret them (Plomin, 1994). Proximal environments are, in effect, people's "extended phenotypes" (Plomin & Bergeman, 1991, p. 374), and they can be studied with the same behavioral genetic techniques as are measures of intelligence and personality. This sort of genetic research "consistently shows that family environment, peer groups, social support, and life events often show as much genetic influence as do measures of personality" (Plomin, DeFries et al., 1997, pp. 203–204).

Consider the HOME, which measures aspects of the home environment such as parental responsivity, encouraging developmental advance, and provision of toys. HOME ratings of sibling-specific parental behavior at ages 1 and 2 were found to be more similar for nonadoptive (.58 and .57) than for adoptive siblings (.35 and .40), and model fitting confirmed a heritability of 40% for the HOME (Braungart, Fulker, & Plomin, 1992). The HOME, in turn, is correlated with cognitive development later in childhood. It turns out, in fact, that half of the HOME's ability to predict cognitive development can be accounted for by that measure's (child-generated) genetic component (Plomin, 1994, p. 122). In other words, effects of the rearing "environment" are due partly to the effects of the child's own genotype acting through the environment created by and for that unique individual.

Videotaped and observational studies also show that parental interaction with infants and adolescents is heritable, especially for child-initiated interaction (Dunn & Plomin, 1986; Lytton, 1977, 1980; O'Connor, Hetherington, Reiss, & Plomin, 1995). Ratings of rearing environments obtained retrospectively via questionnaires are likewise routinely found to be heritable. For instance, adult identical twins raised apart (or together) rated their childhood environments more similarly than did fraternal twins raised apart (or together), yielding heritabilities of about 0.4 for parental warmth, 0.2 for emphasis on personal growth, and 0.1 for parental control (Plomin, McClearn, Pedersen, Nesselroade, & Bergeman, 1988).

It is easy to see how *perceived* environments might be partly genetic in origin, because individuals come to situations with different dispositions and capacities for interpreting the world around them. Some people may be more inclined to perceive warmth in others. But as just described, objectively ascertained environments can also originate partly in the genotypes of their presumed targets of socialization. It is likely, as in the case of the adult twins just mentioned, that phenotypic differences among children evoke different responses (more versus less warmth) from family members. Parental behavior, then, is partly the extended phenotype of the child. Nurture responds to nature, to genetically driven individuality.

An aspect of "environmental genetics," the foregoing results warn us that our measures of "environment" are not necessarily entirely nongenetic (for examples, see Baumeister & Bacharach, 1996; Longstreth, Davis, Carter, Flint, Owen, Rickert, & Taylor, 1981). A little reflection reveals that family environments, like classroom environments (Sizer, 1984), are often negotiated with charges rather than imposed upon them. We should also be warned that, as discussed above, even if the individuals subjected to an environment had no role in creating it, they will experience that environment only as they interpret it. Moreover, they may remake it in ways never intended. Such may be the fate of some vocational interventions that have had weak or spotty effects: The experience received was not the experience intended. The intervention checks that reveal this "experimental noise" can perhaps provide grist for the developmental study of person–environment interaction. Just how *do* children perceive, experience, and deflect attempts to influence their traits and behaviors?

Although the transmutation of intended environments by recipients can be frustrating to socialization agents, it may be the heart of the adjustment process throughout life, whether personal or vocational. Greater person–environment fit can be achieved by just moving to a more congenial environment, but that is not always an option. There is often leeway, however, to remake elements of home, school, and work settings for greater satisfaction (albeit sometimes to the consternation of other occupants). Many people have to compromise their goals, but they differ in the extent to which they can "make lemonade out of lemons" and in how they do so.

In sum, vocational psychology might benefit by rethinking how to measure rearing environments and by investigating individual differences in how people create and remake objectively measured environments, including vocational interventions.

Shared Family Effects on IQ Dissipate by Adolescence

Behavioral genetic evidence is clear in showing that not all environmental effects are genetically mediated. What does the research say, then, about environmental effects that are independent of genes? Behavioral geneticists expected the research to confirm what Rowe (1997) calls "family effects theory," namely, the widespread assumption that family circumstances (parental education, occupation, income, etc.) and child rearing styles (cold, authoritative, etc.) mold children permanently in fundamental ways. What the research actually shows, however, is that we have badly misunderstood how the environment works.

Behavioral genetics partitions environmental effects into two classes—shared and nonshared (also referred to as between- and within-family effects). *Shared* effects are those aspects of the rearing environment that siblings share in common and that make them more similar. As just noted, most developmental theories have assumed that shared features of the environment, such as parental education, social class, and parenting style, indelibly shape their children's personal traits. *Nonshared* effects are those events and circumstances that affect the development of one sibling but not another. These effects make siblings more different. They may include illness, parental favoritism, different peers, and the like. Environmental effects are parallel in this sense to the effects of genes on siblings—they can create both similarity and difference within families. The 50% of segregating genes that siblings share on the average makes them phenotypically similar, but the 50% they do not share ensures that siblings will differ among themselves (and from each of their parents, with whom they also share only 50% of their segregating genes).

There are several ways to estimate the proportion of phenotypic variation that is due to shared versus nonshared environments. The correlation between adopted siblings provides a direct estimate of shared effects, because the only family heritage they share is environmental. Shared effects can also be estimated by subtracting the correlation between identical (or fraternal) twins who were reared apart from the correlation for identical (or fraternal) twins reared together. Being 100% (or 50%) alike genetically, any additional similarity between the twins reared together must be due to the environments they shared. The remaining phenotypic variance (i.e., that which is not explained by either genetic or shared environmental effects) is due to nonshared environments and measurement error. Variance due to nonshared effects can be directly estimated by the phenotypic dissimilarity of identical twins reared together or apart (after subtracting measurement error), those reared together generating a smaller estimate if shared environments have made them more similar.

As already discussed, the "environmentality" of IQ drops with age. The question, then, is whether it is mostly the shared or the nonshared component of environmental effects that dissipates with age. The answer was entirely unexpected: Shared effects on IQ become nil by adolescence. Genetic factors, nonshared environment, and shared environment appear to account for, respectively, 40%, 25%, and 25% of phenotypic variance in childhood (10% measurement error) but for 60%, 35%, and 0% (with 5% for error) just after adolescence (Loehlin, Horn, & Willerman, 1989; Plomin, DeFries et al., 1997, p. 150). Longitudinal studies of adoptive families show that as adoptive children grow up they become less like their adoptive parents (the correlation drops to zero) and more like the biological parents and siblings they may never have seen (Loehlin, Horn, & Willerman, 1989; Scarr & Weinberg, 1978). By the same token, biological siblings who have grown up together become less alike as the effects of their shared environments dissipate.

These results are momentous because they indicate that the class of causes that most social scientists still assume to be most powerful in creating IQ differences in typical environments actually have no lasting impact on IQ. Conversely, the research has revealed a very important class of nongenetic effects hitherto ignored. Scarr's theory provides an explanation for why shared effects might dissipate by adulthood: Children become increasingly independent of their families with age. However, the discovery of substantial nonshared effects across the life span presents an enormous new puzzle: What do they consist of? What can it be that is so important in development but that affects the IQ of only one sibling in a home and creates no differences between families (no shared effects)? The most systematic treatment of the question for IQ (Jensen, 1997) suggests that nonshared influences may not be psychosocial or systematic but mostly biological and akin to random noise in development.

To what extent do the foregoing results on shared versus nonshared environments generalize to other career-relevant traits? Shared effects for personality, psychopathology, and social attitudes are negligible even in childhood, except for delinquency (Rowe, 1994), and shared effects on antisocial behavior mostly dissipate by adulthood (Lyons, 1996). Even weight and attitudes toward eating and weight turn out to be unaffected by shared family environments (Grilo & Pogue-Geile, 1991; Rutherford, McGuffin, Katz, & Murray, 1993). Nonshared effects on nonintellectual traits generally rival or exceed genetic effects. Plomin, DeFries et al. (1997, p. 257) conclude that nonshared influences are, in fact, the general mode by which environments affect psychological development. Counterintuitively, then, rearing environments end up making siblings less alike, not more similar. Siblings lead surprisingly separate lives, even in the same household (Dunn & Plomin, 1990).

But again, what are the nonshared factors that make siblings different? As did Jensen (1997) for IQ, Dunn and Plomin (1990) emphasize the importance of chance in the development of psychological traits (accidents, illness, etc., and the chance concatenation of events). However, they suggest that psychosocial environments may also constitute important sources of nonshared effects on development: for example, differential parent-child relationships, differential experiences within the sibling relationship, the impact of growing up with an individual very different from oneself, and influences beyond the family. However, efforts to identify those nonshared psychosocial effects have met with limited success, generally accounting for no more than 2% to 10% of the nonshared effect (McGue & Bouchard, 1998). In contrast, studies are beginning to indicate that pre- and perinatal factors, including obstetrical complications, may account for a significant portion of the nonshared effects on psychopathology (e.g., schizophrenia).

With regard to vocational interests, what little evidence there is tells much the same story: Environmental effects are mostly of the nonshared variety. Betsworth et al. (1994) modeled *Strong* vocational interest data for twins reared together, twins reared apart, adoptive families, and biological families. The results suggest that the variance in a wide range of vocational interests (*Strong* General Occupational Themes as well as Basic Interest Scales) can be attributed 36% to genetic variance, 9% to shared environment, and 55% to nonshared environmental effects and measurement error. The results were very similar for all six Holland themes of work.

By these estimates genetic effects are four times as large as shared family effects. The importance of shared effects relative to nonshared ones is less clear, however, because the 55% estimate for the latter includes measurement error, which may be a bit larger in this study than others. The great strength of the Betsworth et al. study is that it combined studies of interests from different family types, but this necessitated a tradeoff in reliability of measurement.

The constituent studies had used different forms of the *Strong Interest Inventory*, so the behavioral genetic modeling was based on only those interest items that were common across all studies. Longer, more reliable scales would have yielded higher heritabilities and shared environmental effects and reduced the nonshared plus error component of variance. To illustrate, Bouchard (1997b) showed that the heritabilities of the six general occupational themes (Realistic, Investigative, etc.) averaged .32 in a sample of about 50 adult twins reared apart when assessed with the brief scales in the Betsworth et al. study but that the heritabilities averaged .38 using the full SCII scales and .50 using factor scores derived from the SCII and a second interest inventory. Higher scale reliability would also be expected to increase the estimate of shared effects, but they would still be a relatively small proportion of total phenotypic variance. The bottom line is that, unlike for intelligence and personality, shared environments may have some lasting effects on adult vocational interests. Nonetheless, consistent with those other traits, vocational interests seem to stem primarily from genetic and *non*shared environmental factors.

Estimates such as those of Betsworth et al. are of the *total* effect that *all* shared (or nonshared), nongenetic influences exert in the population studied. However, behavioral genetic designs can incorporate measures of specific events or circumstances for individual children (e.g., each sibling's perceptions of parental warmth, divorce, or encouragement) in order to test hypotheses about whether they constitute either shared or nonshared influences. For example, Pike, McGuire, Hetherington, Reiss, and Plomin (1996b) confirmed that parental negativity may create nonshared effects on adolescent adjustment when they found a correlation between *differences* in parents' negativity toward their identical twins and *differences* in those twins' adjustment. In this case, environmental effects were small (Pike, McGuire, Hetherington, Reiss, & Plomin, 1996a), but the research illustrates how behavioral genetic research can help identify which specific elements of rearing environments may have affected development.

Vocational researchers might consider studying nonshared effects, but doing so requires studying more than one child per family and measuring environments specific to each child. It now appears that it is precisely the differences between siblings that hold greatest promise for understanding environmental effects on development. It is not that family environments are unimportant in creating individual differences in stable traits but rather that their effects tend to be specific to each child. Environments as well as genes enhance individuality.

Intelligence, Special Abilities, and School Achievement Have Common Genetic Roots

The structure or architecture of (phenotypic) aptitudes has been a major issue in the study of human intelligence. Factor analysis produces a hierarchical picture of aptitudes, with *g* (general intelligence) at the top (Carroll, 1993). The next level is comprised of more specific aptitudes such as verbal, spatial, mathematical reasoning, and speed of processing. Further down the hierarchy are the more elementary processes involved in processing cognitive input. Factor analyses suggest that tests of specific aptitudes measure *g* more than they do any specific aptitude, and behavioral genetic analyses show these aptitudes to be heritable in proportion to their correlation with *g*. Individual differences in scholastic achievement and grades are also moderately to highly correlated with *g*, as well as being moderately heritable (Plomin, DeFries et al., 1997, pp. 164–166). But to what extent does this overlap among traits arise from common genetic or environmental roots?

This is the realm of multivariate genetic analysis. It investigates the sources of *co*variance between two traits rather than of the variance in a single trait. For example, instead of correlating one twin's verbal score with the co-twin's verbal score, a twin's verbal score is correlated with the co-twin's *spatial* score. The same rules of inference apply as for the analyses of trait variance: If the cross-twin correlations are greater for identical than fraternal twins, they constitute evidence of genetic influence in the covariance.

To the surprise of many, the same genetic factors tend to influence different mental abilities. To the extent that special abilities phenotypically overlap each other and *g*, that overlap is mostly due to a common genetic source. Only a small portion of the heritability of the specific aptitudes is not related to *g*. The same general pattern is found for the correlation (about .5) between scholastic achievement and intelligence (Thompson, Detterman, & Plomin, 1991; Wadsworth, 1994). To the degree that achievement and IQ correlate, their similarity is almost entirely genetic in the populations studied (Jensen, 1998). Conversely, it appears that the divergence between the two is mostly environmental.

There are multivariate genetic analyses for personality but none that I know of for vocational interests. Those for personality highlight the sorts of questions that could be asked for interests. All could provide novel kinds of evidence for the construct validity of different interest measures, as is illustrated by the following three examples from the personality domain. Largely the same genetic factors are involved in twins' self-reports as in peers' ratings of their personality. Parents' ratings are odd by contrast, often being less genetic and more subject to contrast effects (i.e., exaggerating the differences between siblings; Plomin, DeFries et al., 1997, pp. 199–200). The second example is that the genetic variation in the personality trait of neuroticism largely accounts for genetic variation in symptoms of anxiety and depression (Eaves, Eysenck, & Martin, 1989). The three attributes thus have much the same genetic roots. (Their environmental roots are somewhat less similar.) Lastly, although not doing a multivariate analysis per se, Loehlin (1992, ch. 4) showed that subtraits (e.g., impulsivity) within the individual "Big Five" personality dimensions (extraversion) show unique genetic variance not shared with other subtraits (sociability) in the factor. As Plomin, DeFries et al. (1997, p. 198) suggest, multivariate genetic analyses can compare different ways to "slice" the personality domain.

Multivariate genetic analyses could be used to address some of the longest-running debates concerning vocational interests: What is the most accurate structural representation of interests (Rounds, 1995), and do personality and interests represent two domains or one (Waller, Lykken, & Tellegen, 1995)? Where psychometrics has its hierarchy, vocational psychology has its hexagon. In contrast to the broad dimensions of mental ability, all of which manifest generally the same moderate degree of relation with each other, broad-band interests (e.g., Realistic, Investigative) correlate more highly with some among them than others, but in a definite pattern, and one that produces Holland's famous RIASEC hexagon (Holland, 1997).

The question, then, is what accounts for the systematic patterns of similarity and difference around the hexagon. Holland (1997) describes his six interest types as "personality types," each with its distinctive cluster of attitudes, beliefs, preferences, and personal styles. The six types are not traits in the usual sense but are configurations of different personality traits (extraversion, traditionalism, sensation-seeking, etc.), for most of which there are heritability data. If the formulations of the types are correct, then multivariate genetic analyses should reveal a pattern of genetic overlap and nonoverlap around the hexagon, both overall and for particular personality traits, that is consistent with the formulation of the types.

For example, Conventional and Realistic types are described as being traditional and conforming, whereas Investigative and Artistic types are nonconforming. Because traditionalism (conservatism versus liberalism) is heritable (Bouchard, 1997b; Lykken, 1982), multivariate analyses could be expected to show not only that Conventional and Realistic interests share genetic variance with each other that they do not with the Investigative and Artistic interests but also that part of that shared genetic variance relates to traditionalism. On the other hand, Investigative types are cautious and retiring but Artistic types are impulsive and expressive, so there is genetic variance they could be expected to share with other types (respectively, Realistic and Enterprising) but not each other. Holland says little about the relation of the types to mental abilities, but there is probably some genetic overlap between particular interests and abilities too. Investigative work, for example, seems to require higher *g* than do the other interest categories. To take an example regarding specific aptitudes, spatial aptitude might share genetic variance with interests in mid- to high-level Realistic work. Some of these relations have already been observed at the phenotypic level (Ackerman & Heggestad, 1997). Genetically sensitive research could estimate to what extent such similarities around the hexagon are due to common environmental versus common genetic sources of variance, thus producing new evidence concerning the meaning and structure of vocational interests.

Such analysis would simultaneously inform the "how many domains?" debate. If the most general or broad-band interests reflect personality best, as Holland (this volume) states, then the multivariate genetic analyses just suggested should provide evidence relevant to his claim that interests are, in fact, measures of personality. Multivariate behavioral genetic analysis could also answer a question with a long-standing parallel in the study of mental abilities: What is the genetic overlap between general and specific measures of interests? And what is the overlap between self-ratings and behavioral measures of interests?

IQ Stability Is Mostly Genetic in Origin Whereas Age-to-Age Change Is Mostly Environmental in Origin

Some of a person's environments change considerably over the life cycle, but others may not. Some genes turn on or off during development and others have different effects at different ages, which means that heritability does not necessarily imply stability. Both environments and genes can produce stability and change.

The most informative research for studying the sources of stability and change are longitudinal, genetically sensitive designs that measure traits, behaviors, and environments at periodic intervals beginning in early childhood. Examples include the Colorado Adoption Project, the MacArthur Longitudinal Twin Study, the Twin Infant Project (see Fulker, Cherney, & Cardon, 1993, for these three), and the Texas Adoption Project (Loehlin, Horn, & Willerman, 1989). They have used model fitting to determine whether new environmental or genetic influences appear at successive ages.

Such studies for intelligence show that genes contribute primarily to stability rather than change in IQ relative to one's age peers. There is some evidence of genetic change, especially at certain transitions in childhood. One occurs soon after children enter school, suggesting a g–e interaction when children are introduced to this novel environment (i.e., some children are genetically more sensitive or responsive to schooling). Shared environmental factors apparently contribute only to IQ stability in childhood, but nonshared effects (which are the only environmental effects on IQ from adolescence on) are the major source of age-to-age change in IQ relative to age-mates. Moreover, nonshared effects contribute only to change in IQ (Fulker et al., 1993, p. 93). To keep the change data in perspective it should be noted that IQ is relatively stable. Research on elementary school children shows that most change in IQ is either negligible or due to measurement error. Where change is marked and real, it tends to be idiosyncratic and transient (Moffitt, Caspi, Harkness, & Silva, 1993).

There is less behavioral genetic evidence concerning the sources of stability and change in personality, but the findings are similar to those for cognitive ability. It appears that there is little genetic influence on change in personality, that most genetically induced change occurs during childhood, and that it is larger for some traits (reactivity) than others (shyness; Plomin, DeFries et al., 1997, pp. 202–203). Genes promote primarily stability of personality. Most change is due to nonshared environmental effects (Bouchard, 1995; Loehlin, 1992).

I am not aware of any pertinent evidence on the genetic versus environmental sources of stability and change in vocational interests. Considering that interests are fairly stable from adolescence on (Swanson, this volume), we might expect to find much the same picture for interests as for personality, especially if there is genetic overlap between the two realms. Clearly, however, most of the developmental action occurs prior to adolescence, and we do not have even the most basic knowledge about the development and nature of vocational interests in childhood.

Do interests even exist in early childhood in the same sense that personality does, and if so, how can we measure them? It takes time for specific abilities to differentiate, and it may be so with interests too. Do interests begin crystallizing—becoming "traited"—only after substantial and relevant interaction with environments? Some behavioral geneticists have begun to speculate that this is the case. Lykken, Bouchard, McGue, and Tellegen (1993) suggest that "precursor traits" closer to the genetic level, such as physique, aptitude, temperament, and personality, help determine which experiences an individual selects from a given "cafeteria of experience" as well as how the individual reacts to those experiences. Social convention affects what is in the cafeteria, and interests that are not experienced do not become well traited. As a result, those particular interests may be unstable as environments change or individuals move out of them.

Lykken et al. suggest, then, that stability comes with traitedness, the crystallization of which comes with relevant experiences initiated in large part by prior genetic dispositions. In contrast, theories in vocational psychology have generally attributed stability in interests largely to the environment. For example, although Holland's (1997) recent theorizing is sensitive to the interaction of genes and environments, he views personality dispositions as the result (not the cause) of accumulated learning and experience. Here, then, are two competing views about the early development of vocational personalities and interests that could help guide research on the origins and development of interests. Although Lykken et al.'s theory seems more consistent with the evidence on intelligence and personality, it is not clear yet that vocational interests are genetically comparable to those traits. Recall that Holland's six vocational personality types seem to be affected by shared family influence in adolescence but the former traits do not.

REFLECTIONS ON COUNSELING

The guidance that behavioral genetics provides counselors so far is of a general rather than specific nature. It cannot be specific because the research currently says more about what aspects of the environment do *not* seem to have much affect on psychological development (i.e., shared family influences) than what do (i.e., particular aspects of nonshared environments). What it says of a general nature, however, should reassure the counseling field, both by confirming its fundamental orientations and illuminating some of its challenges.

Human Agency and Individuality

Counseling psychology regards individuals as active agents in their own self-development. Behavioral genetics supports this perspective by showing that our fates in life are not "determined" or "fixed" by either our genes or our environments.

Hereditarians and environmentalists have both been mistaken. Rather, we become who we are through our *experiences*, which emerge from the complex interplay between our genes and our environments. That interplay is far from understood, but its very existence confirms that we are by nature active, seeking, self-creating beings, working incessantly to mold, remake, and exploit environments to our needs and tastes. Our genes do not predestine who we become, but they do assure that we will take an active hand in creating ourselves.

Genes assure not only that we help steer our own course of development but also that our inner gyroscopes differ from birth. Our genes do not predestine our paths, but they do attract us toward or repel us from different possibilities. The possibilities for us are constrained, of course, by the time, place, and circumstances of our birth. But, as behavioral genetics shows, the environments that we experience and that nudge our development this way and that may be as unique to us as are our genotypes and, indeed, partly because of them. Behavioral genetics thus supports another of counseling psychology's bedrock principles: respect for individuality.

Ethics and Feasibility of Fostering or Frustrating the Expression of Genotypes

People bring genetic individuality with them into the world. That individuality is expressed and enhanced through experience—experience that is increasingly but only partially self-directed over the life span. Much of life consists of seeking and building niches to suit that individuality. In essence, the function of counselors, like that of parents and teachers, is to facilitate this gene-influenced process when it is constructive and to redirect or suppress it when it is not. Therein lie the dilemmas as well as the opportunities of counseling.

Vocational counseling to a large degree involves helping people to develop vocational options that are congruent with their temperaments. To an extent, then, vocational psychology facilitates the phenotypic expression of genotypes, and it does so by helping people to explore, discover, develop, and implement their vocational interests and aptitudes in congruent environments. Deviations from this facilitative process are often thought to be unethical, as when women and minorities are channeled into certain directions on the basis of sex or race regardless of their interests and capabilities.

Deciding to foster person–environment fit is not as simple a matter when the traits in question range from better to worse (abilities) or may be disapproved by society at large (hostile aggressiveness). For instance, we think it perfectly appropriate to encourage bright students to pursue high-level jobs, but we do not approve of encouraging dull students to seek low-level work. So there are times when we refuse, at least openly, to facilitate person–job match. Often we prefer to try to alter the attribute involved (e.g., increase aptitudes). And there are times when we would actively interfere with person–environment match if we possibly could (e.g., the search for peers with whom to express antisocial tendencies). These are issues with which counselors are uncomfortable. Unlike parents and even teachers, they prefer not to deflect people into or off of certain paths when that seems contrary to the client's desires.

Behavioral genetics provides no guide to the *ethics* of intervening to frustrate or facilitate the expression of genotypes (even if we could discern individuals' genotypes, which we cannot). It does, however, provide some hints as to the *feasibility* of doing so. Facilitating or suppressing the development of certain phenotypes is no doubt easiest when the intervention works in tandem with—not contrary to—the underlying genotypes. "Educating" people into or out of trait-like behaviors is probably difficult to impossible when the genotype is not propitious. For instance, efforts to interest women in engineering will work better with the relatively few women who have Realistic propensities than with the many who have Social proclivities. Extensive exposure of girls with Social interests to Realistic developmental opportunities is unlikely to engender enduring Realistic interests in many, if any, such girls.

To take another example, efforts to prevent drug use, risky sex, and smoking by educating youngsters about the risks of such behavior will probably have the least effect on the individuals who need it most: those at greatest genetic risk. Such individuals may be better protected by closing off or closely monitoring opportunities to engage in such behavior, as some parents can attest, or by somehow diverting youngsters into more constructive activities. Stated another way, because some individuals are more sensitive to exposure (stress, temptation), it may be more feasible to protect them from exposure than to decrease their sensitivity to exposure. Nonetheless, just as increasing one's exposure to good developmental environments often may do little to enhance a valued trait, minimizing exposure to risk may have limited effect in suppressing problematic traits that are in part genetically propelled.

Responsibilities Regarding Individuality Versus Variability

The counseling profession is ambivalent, as are many others, about individuality itself. Individuality produces variability, and variability often means inequality. Variability is fine only when it involves no invidious distinctions. Differences in

interests are welcome, for instance, but differences in ability are not, often leading to confusion and inconsistency in the guidance that counselors get and give. As shown above, differences in abilities as well as interests are both substantially heritable in the populations vocational counselors serve, although the dilemmas for counselors would be the same were stability to result from environments rather than genes. There is nothing counselors or society can do to make all people equal in ability or any other valued trait, except perhaps to take the dubious step of inducing negative ("compensatory") genotype–environment correlations (i.e., providing the worst environments to the most favorable genotypes and the best environments to the least favorable genotypes). Variability can be increased or reduced somewhat, but it will always be substantial.

In any case, it is not the business of counselors to increase or decrease phenotypic variability, no matter how they feel about it. Their job is to enhance individual development, either by working with individuals or their environments (families, schools, etc.). Valuing individuality means accepting that variability will emanate from it; they are two sides of the same coin. If counselors seek to overcome the limits of certain genetic as well as environmental constraints, whether by behavioral, pharmacological, or other means, that effort should be aimed at promoting the welfare of individual clients, not reducing variability itself.

Opportunities for Enhancing Specific Versus General Attributes

Behavioral genetic research provides no guidance yet about how counselors might manipulate environments to enhance vocational development, except, as discussed earlier, to help assure broad menus of experience by which young people can discover and develop their talents and interests. It does counsel realism, however, concerning which behaviors may be more versus less malleable under typical circumstances. In particular the moderate to high heritabilities of various general traits suggest that manipulating or redistributing current sociopsychological environments will do little to change the distribution of traits among the vast majority of children in the West. To the extent that chronic debilitating traits (such as depression or anxiety) are rooted in genetic risk rather than conditioned by a lifetime of unfortunate circumstances, there may be nonpsychosocial interventions (e.g., medication) that can provide enough relief for behavioral interventions to have some salutary effect.

The genetically induced stability of highly general (mostly context-free) traits does not mean, however, that important specific skills and behaviors further from the genetic substrate cannot be substantially enhanced. They can, as we see happening everyday in homes, schools, and on the job. As long as environments are adequate for general trait development to proceed, our focus in dealing with individuals at this time (in addition to providing menus of experience) probably ought to be in providing specific opportunities to enhance specific skills. General traits affect the ease with which context-specific skills and behaviors can be trained, but there seems to be much more latitude in enhancing the specific (e.g., setting priorities in career exploration) than the general (vocational maturity).

Genetic Differences Between and Within Subgroups

Just as individuals differ genetically, so too may subgroups of the population. Subgroup diversity makes us even more uncomfortable than does individuality. Behavioral genetics has recently developed methods to investigate the extent to which a mean difference between two subpopulations (between-group variance) is environmental versus genetic in origin (Rowe, 1997). It seems probable, for example, that the worldwide male-female differences in preferences for dealing with things versus people (and thus in Realistic versus Social activities) will be found to have some genetic underpinning. Such genetically influenced subgroup differences would have two important implications for counselors. First, the menus of experience—the social environments—that cultures provide to the two sexes probably differ partly for genetic reasons. (Recall that people's rearing environments are to some extent their "extended phenotypes.") To the extent that gene–environment correlations involving gender generalize to create cultural norms for gender socialization, they are probably targeted to the modal genotypes or average tendencies of a sex. But males and females differ enormously among themselves, so gender-based menus of experience, while perhaps serving the majority of both sexes tolerably well, may stunt the development of the many less typical members of each sex. If anything, then, genetically driven average gender differences in interests and other traits make it even more imperative that young people be exposed to a wide variety of environments. The differences between the subgroups should be respected, but so too should the individual differences within them.

A second implication of genetically based sex differences in psychological traits is that we should not expect the same distributions of interests and occupations among free men and women who have had ample opportunity to explore and develop their individual interests and capabilities. The challenge for counseling, of course, would still be what it is today—to assure individuals the opportunity

to develop. In this context it is important to point out that, although genes probably produce stability of interests, a genetic propensity cannot be inferred from an apparently stable interest. Restricted environments may have limited or stunted the expression of a genotype or imposed on people activities and beliefs that they will discard when given the opportunity. To repeat, optimal development depends on adequate opportunity for exploration and experience.

In summary, behavioral genetics engenders a realism that social science often lacks. Individual differences have genetic roots. So do "environments." Behavioral genetics thereby engenders a more profound respect for the inner forces that propel us forward, each in our particular directions, through the thickets and meadows of circumstance. Listening for the whispers of that genetic substrate as we engage life is part of what constitutes self-understanding. Vocational psychology has yet to know how our genetic inheritance speaks to us and with what effects on our most public of selves, our vocational lives. However, behavioral genetics can help us begin unraveling that mystery by illuminating better the etiology of vocational interests.

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